An Introduction to (some) TPC Calibrations

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(with loads of help from
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Goal of this Talk

Can't possibly explain all the calibrations and how they are done in 30 minutes so I will try to give you simple models and pictures to motivate their need as well as observables that are sensitive to them... AND there will be questions...

TPC Calibrations

Many calibrations! They can be broken up into a few types of calibrations

Static Tracking

- Global Alignment, Twist, and Clocking
- Fine Sector Alignment
- Timing (T0 and Slewing)

Dynamic Tracking

- Drift Velocity
- Spacecharge
- Gridleak
- Beamline Constraint(s)

Only will speak about these in this talk

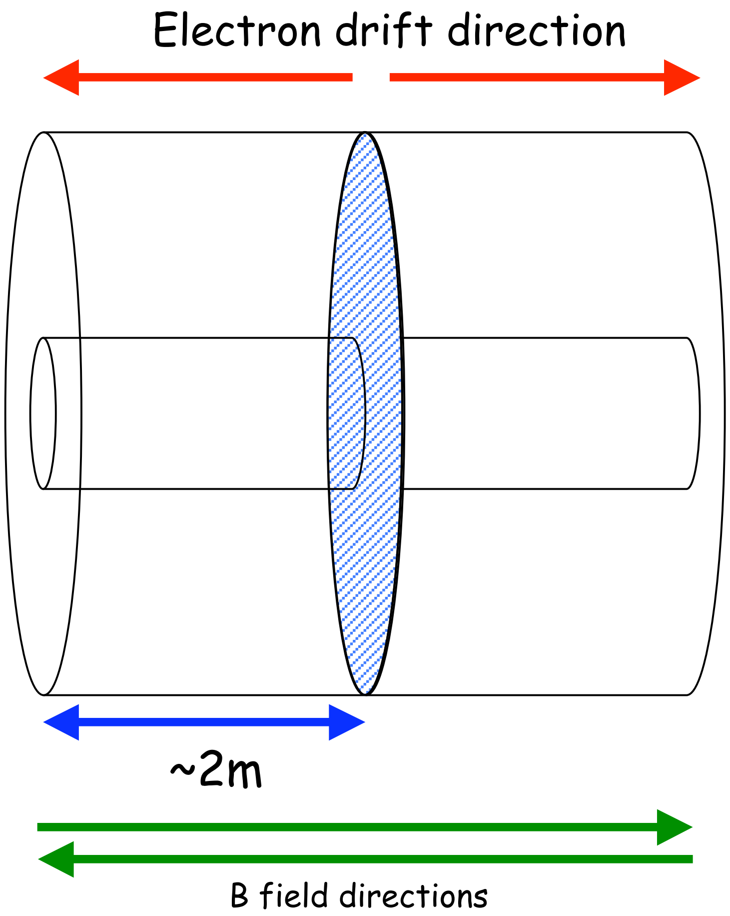
Gains Related

- Pad Pedestals
- Pad Relative Gains
- Absolute Gains
- Slewing

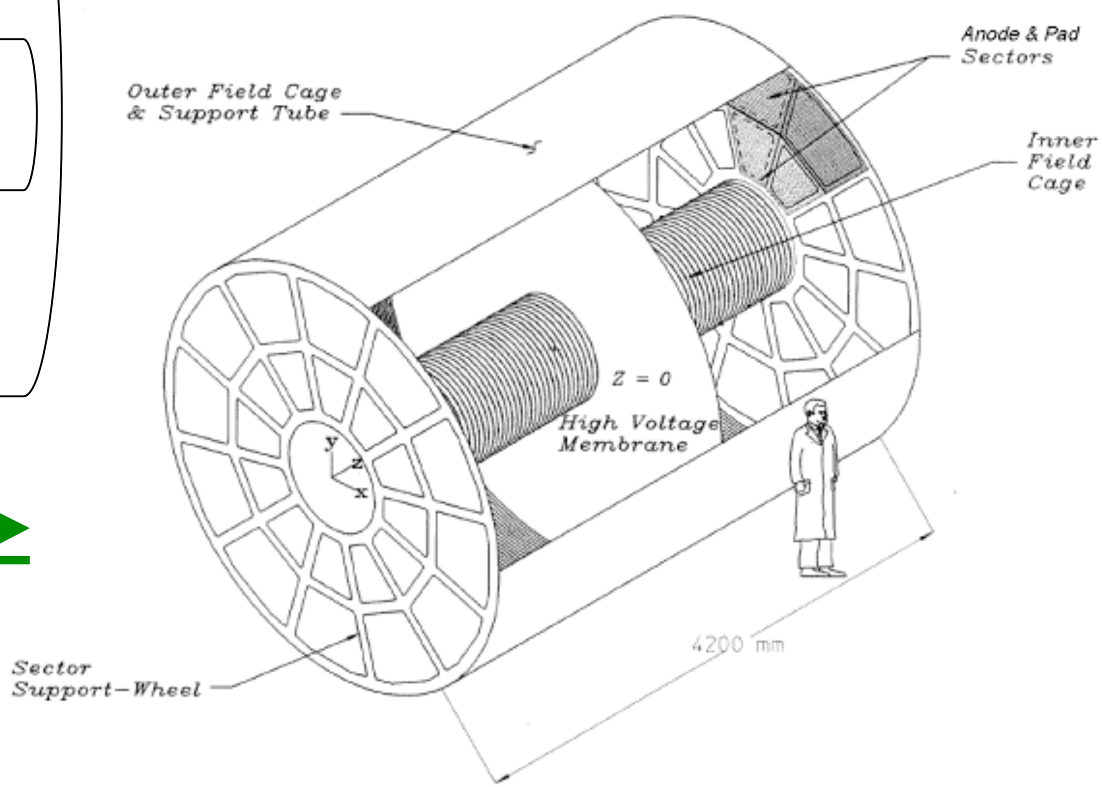
Anomalies and Bookkeeping

- Dead RDOs
- Trips
- Voltage Reductions
- Floating/Dead Wires
- Field Cage Shorts

The TPC - I



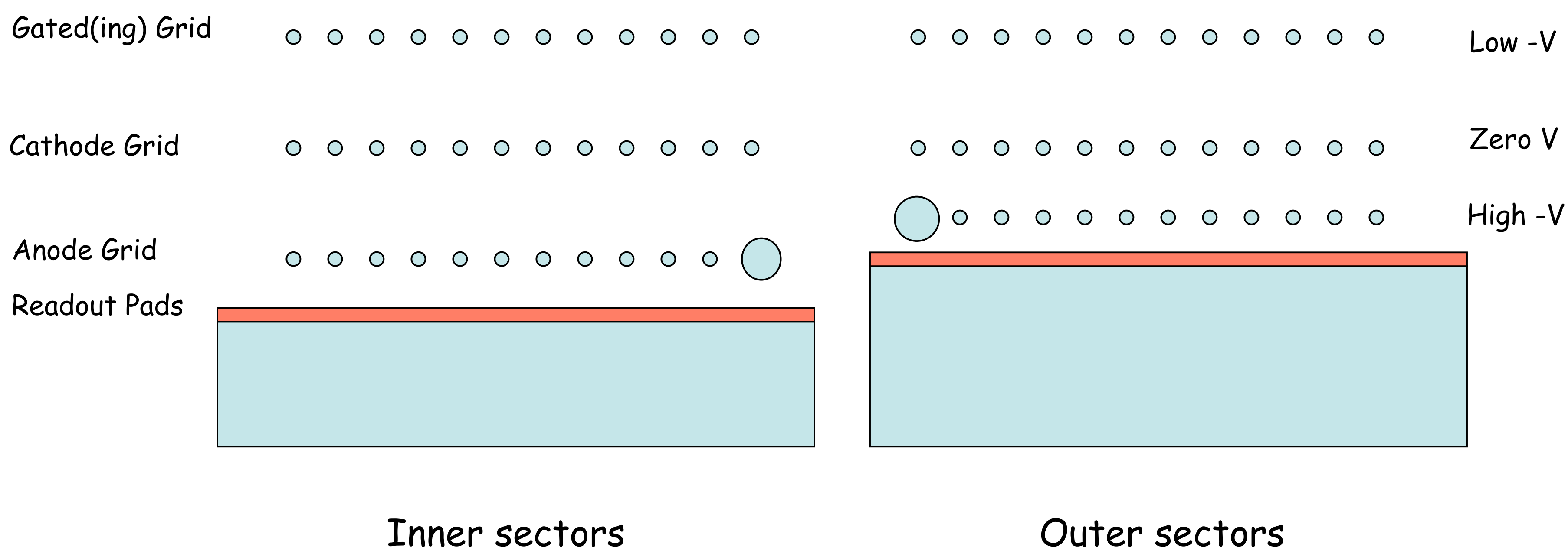
Electron drift direction
~2m
B field directions



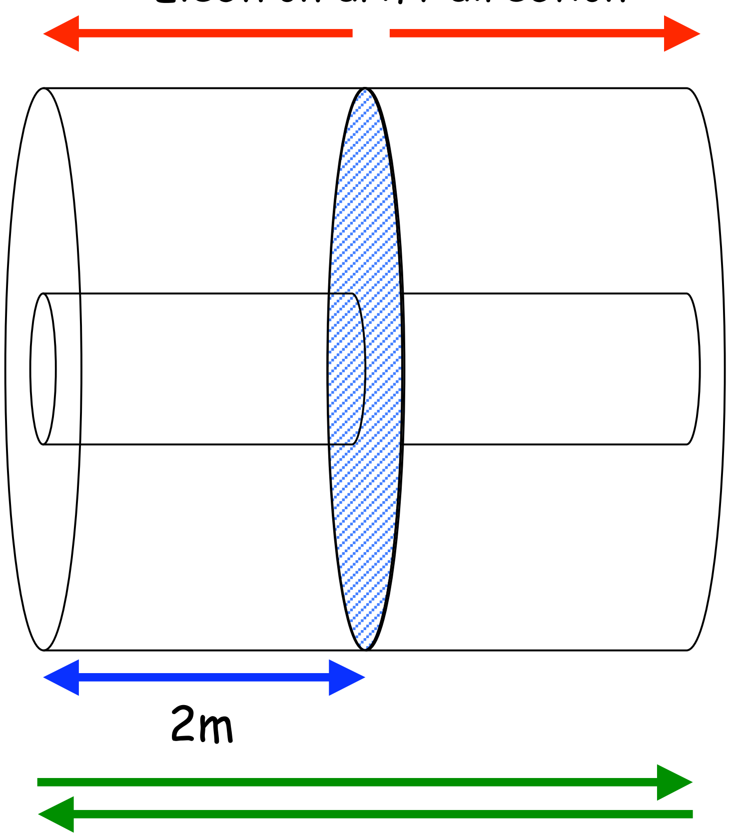
Anode & Pad Sectors
Outer Field Cage & Support Tube
Inner Field Cage
Z = 0
High Voltage Membrane
Sector Support–Wheel
4200 mm

The TPC - II

The readout plane



The TPC - III



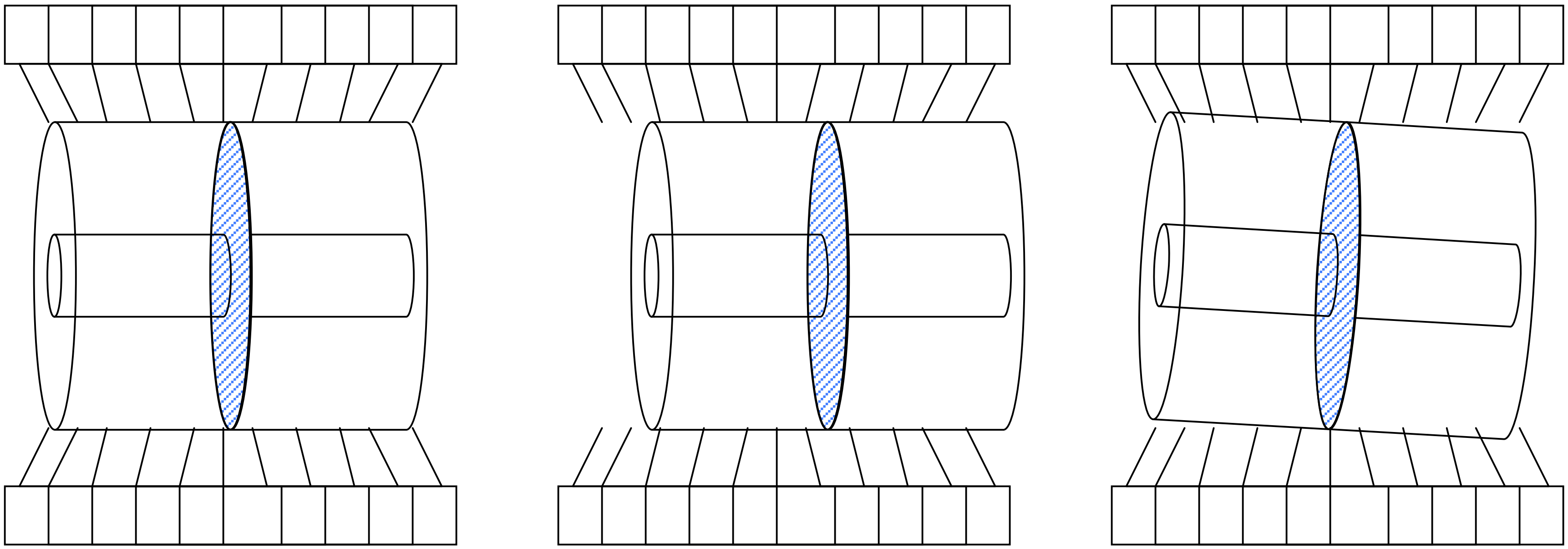
The TPC is a large volume of P10 gas (90% Argon + 10% Methane)

The Ar is the ionizing gas and the methane is the quench gas (quench wha?)

Charged tracks traverse the volume liberating electrons from the Ar causing electron avalanches (eventually clusters) that drift towards the anode side of the TPC at a <velocity> of ~5.5cm/us (dependent on pressure in TPC)

But there are still the ionized Ar^+ atoms. Because of their mass, they drift much more slowly ($\langle v \rangle \sim 5.5\text{cm/us} * m_e/m_{Ar} = 7.5\text{e-}5$ cm/us)

Global Alignment/Twist



Normal

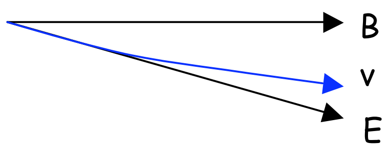
Translation (not ever looked at)

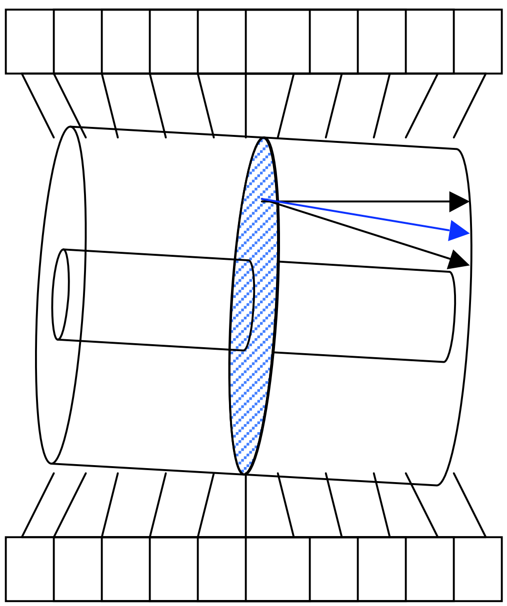
Twist or ExB (done often)

Only really should affect BEMC/TPC alignment

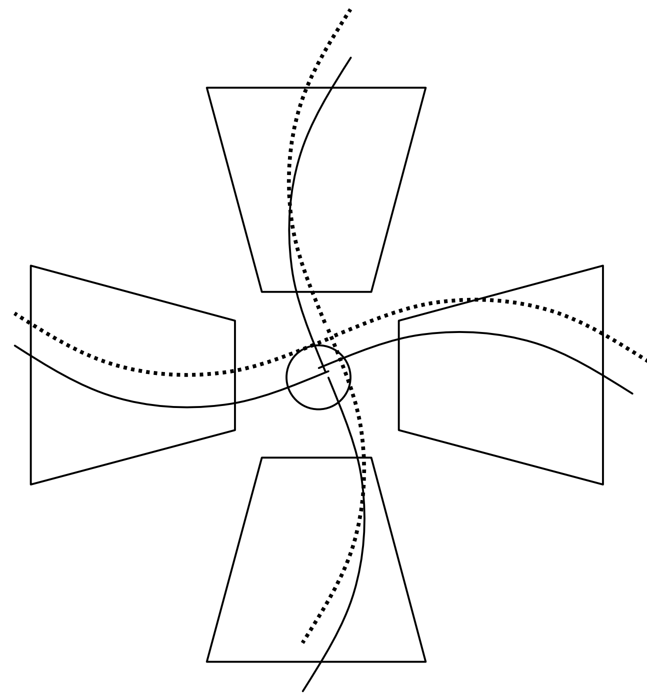
What Does Twist Do?

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) + Stokes$$

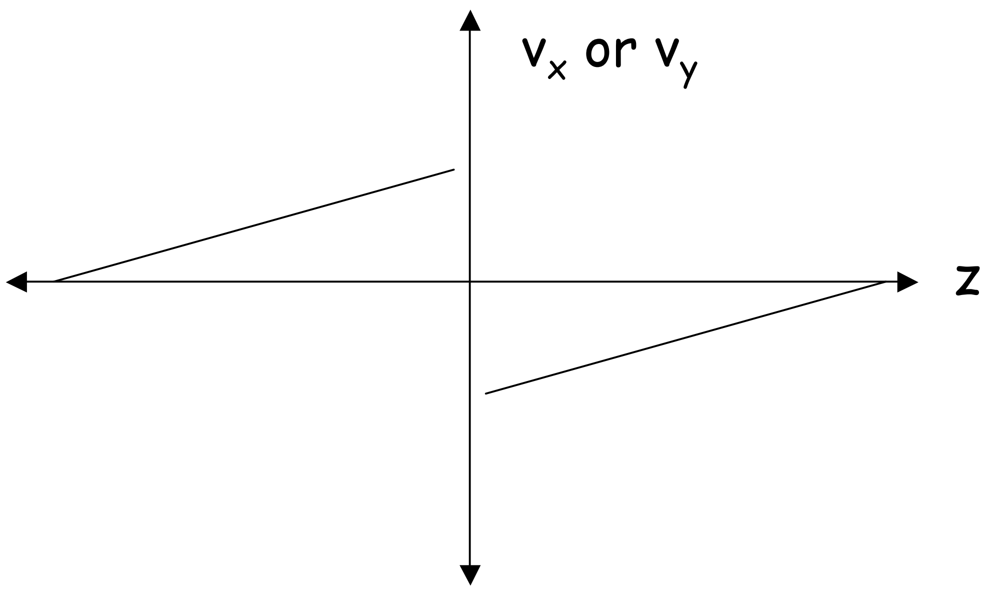




Naively expect that E||B so we expect the clusters to follow the E field, but with a nonzero ExB the trajectories are displaced



How to Measure Twist?

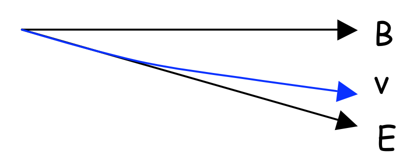


You get a beamline tilt versus z

Do a "beamline constraint" versus z in each half of the TPC separately

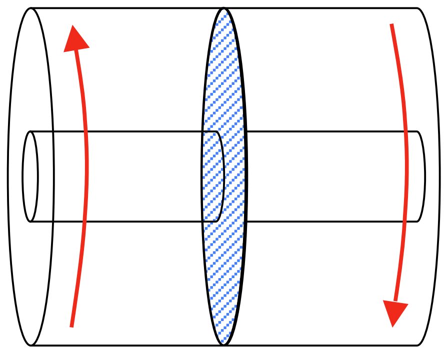
Why do you get a tilt?

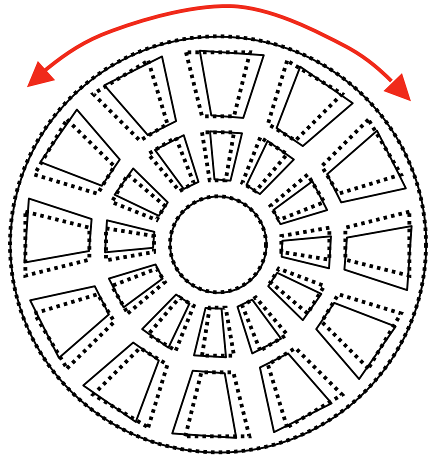
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) + Stokes$$



Clocking

Two halves of TPC are rotated with respect to one another





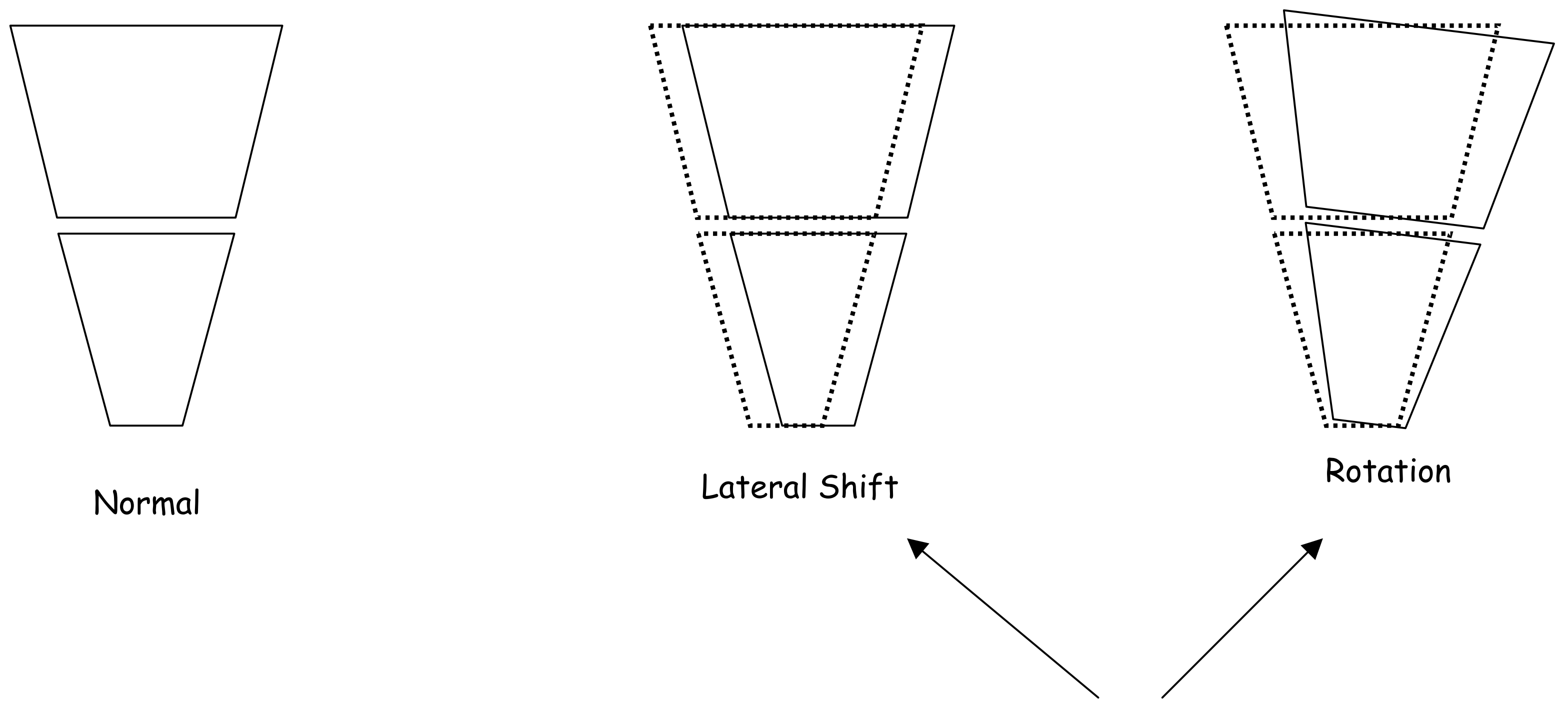
Not done since 2004 (inconclusive results)

If there is a clocking, it will contribute to track splitting at CMB

For brevity I won't talk about how to measure it today

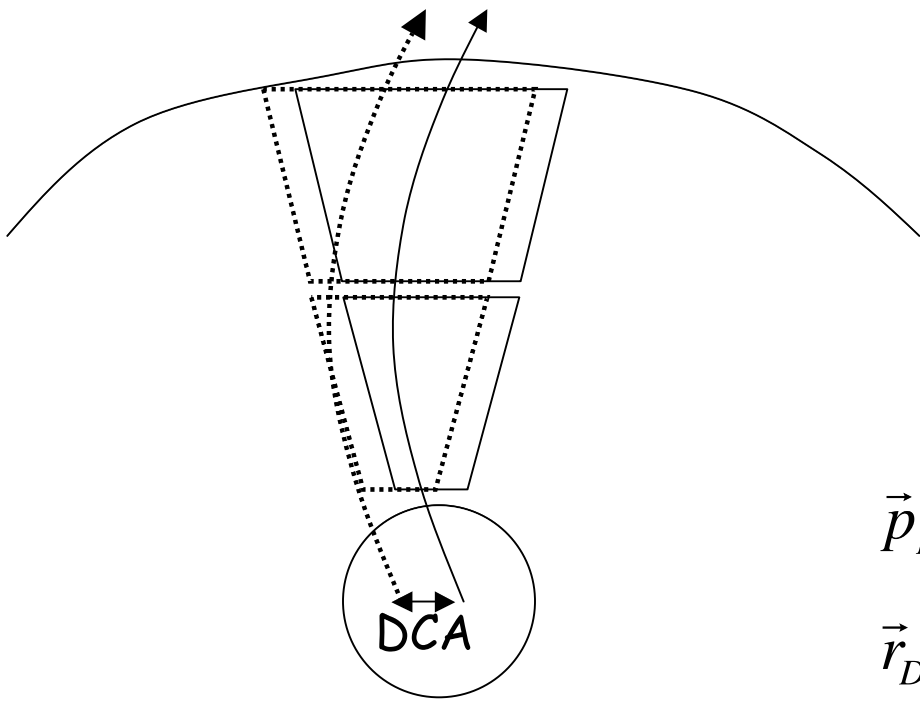
SuperSector Alignment

How sure are we about the alignment of the sectors?
Basically, anything you can imagine is possible



With most methods it is hard to
distinguish these two
(we assume it's rotation)

How to Measure SupSec Misalignment



"signed" DCA

$$\boxed{sDCA = \frac{\left(\vec{p}_{DCA} \times \vec{r}_{DCA}\right)_z}{\left|\left(\vec{p}_{DCA} \times \vec{r}_{DCA}\right)_z\right|}\left|\vec{r}_{DCA}\right|}$$

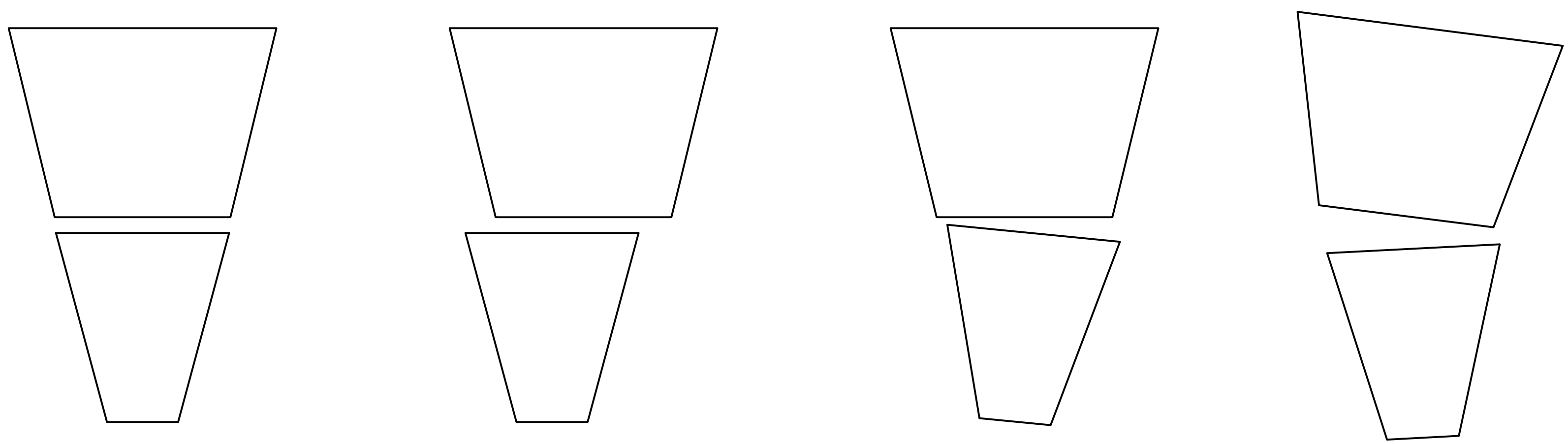
$\vec{p}_{DCA}$ - momentum vector at the DCA to vertex

$\vec{r}_{DCA}$ - vector from DCA to vertex

Measure the sDCA for tracks in a given sector
If there is a misalignment,expect an offset in the sDCA variable in a single sector

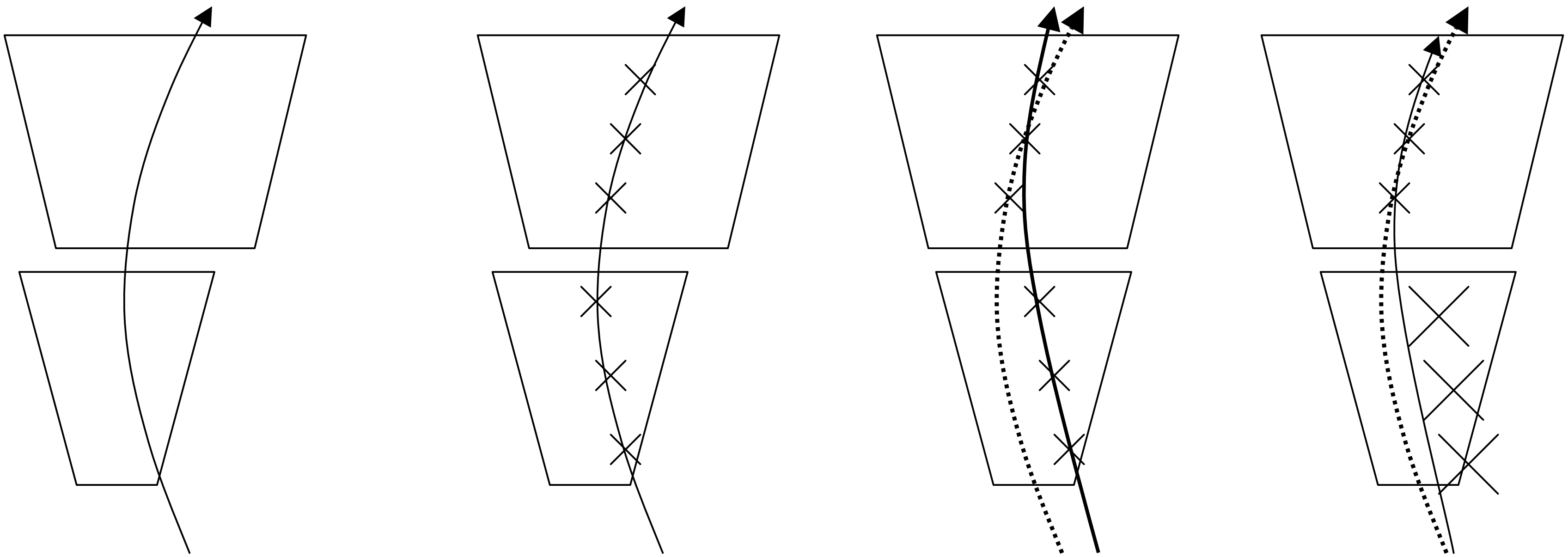
Fine Alignment of Sectors

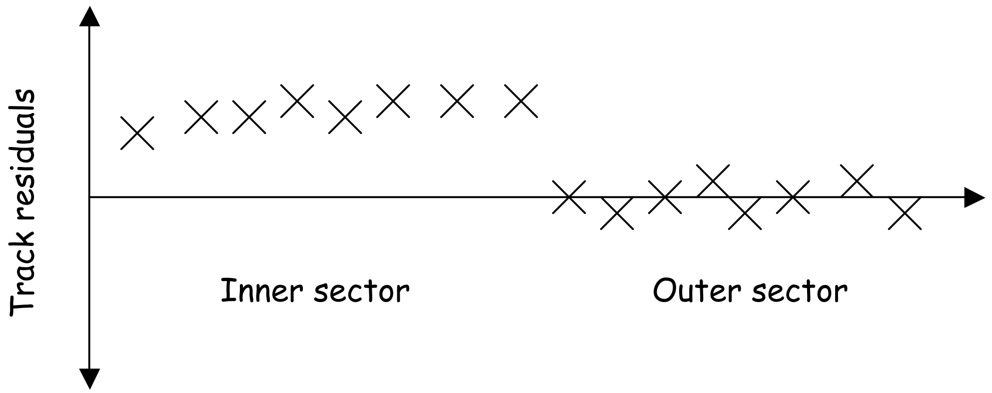
How sure are we about the alignment of the inner and outer sectors?
Again, anything you basically imagine is possible



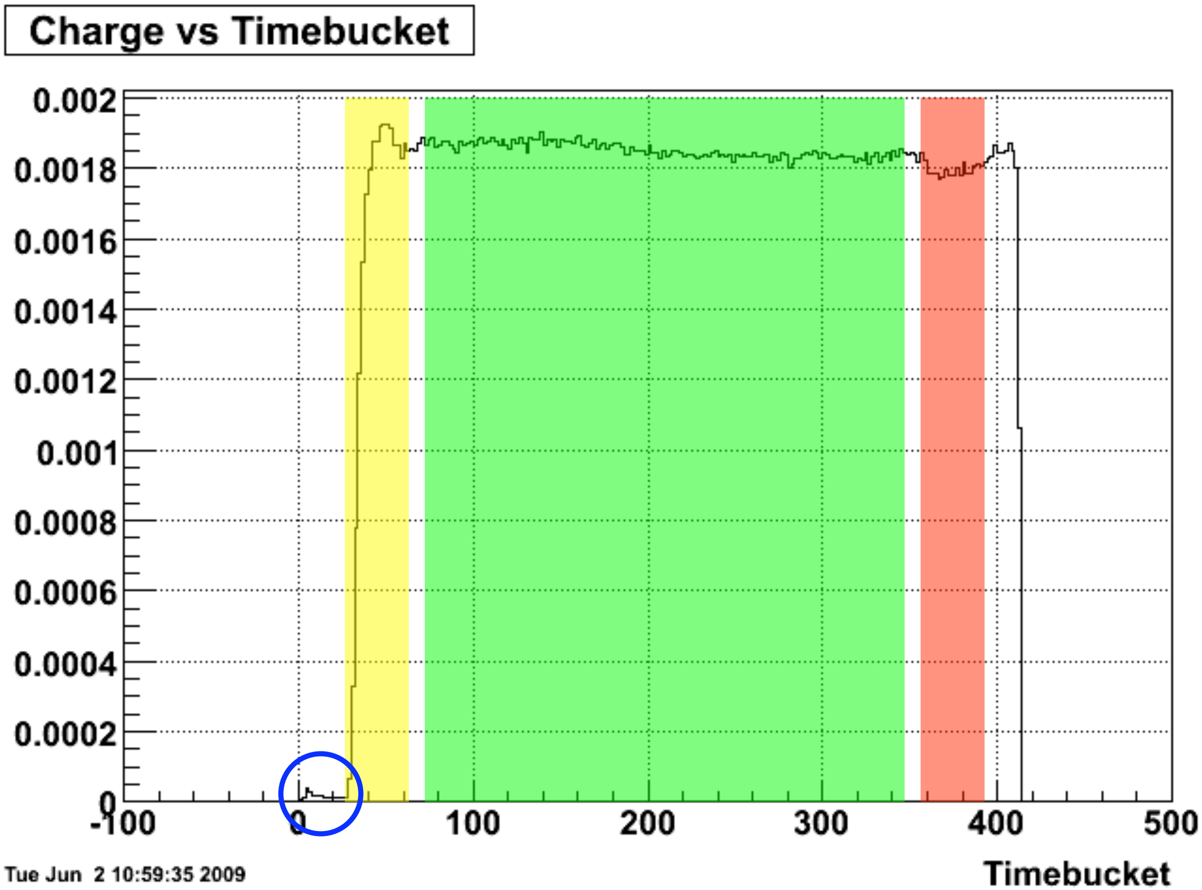
Normal | Lateral Shift | Single Rotation | Double Rotation

How to measure fine misalignment of secs?





T0 (Timing) Calibrations



Charge Step

Normal Charge

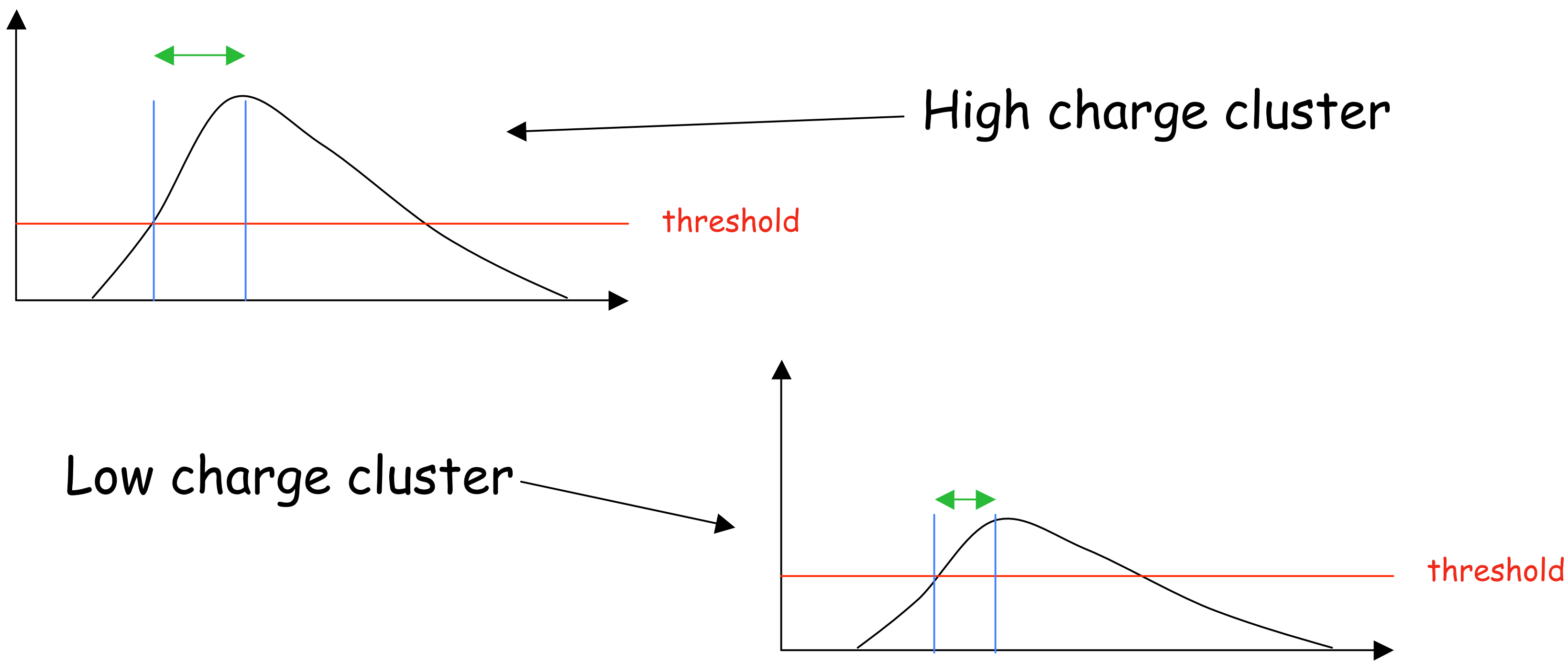
Postmembrane Charge

Prompt Hits

Slewing Correction

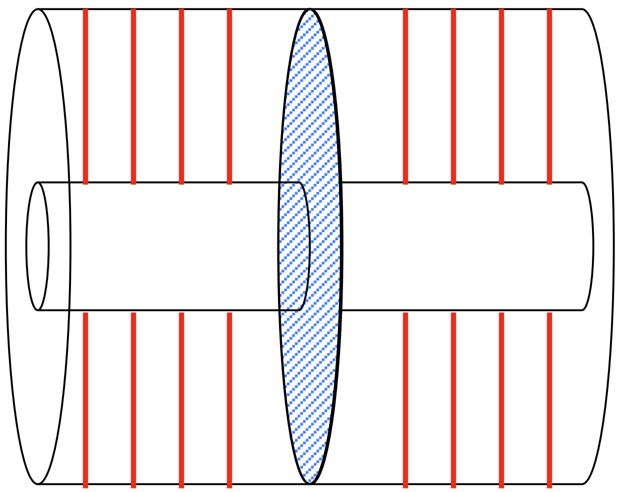
How sure are when about when a cluster arrives? (well sort of…)

With a threshold (common on integrating electronics), the time of a cluster relative to when it starts recording is now energy/charge dependent



Charge dependent correction based on a model of the charge distribution vs. time
Run 9 is the first use of this. So far not seen in Run 10.

Drift Velocity

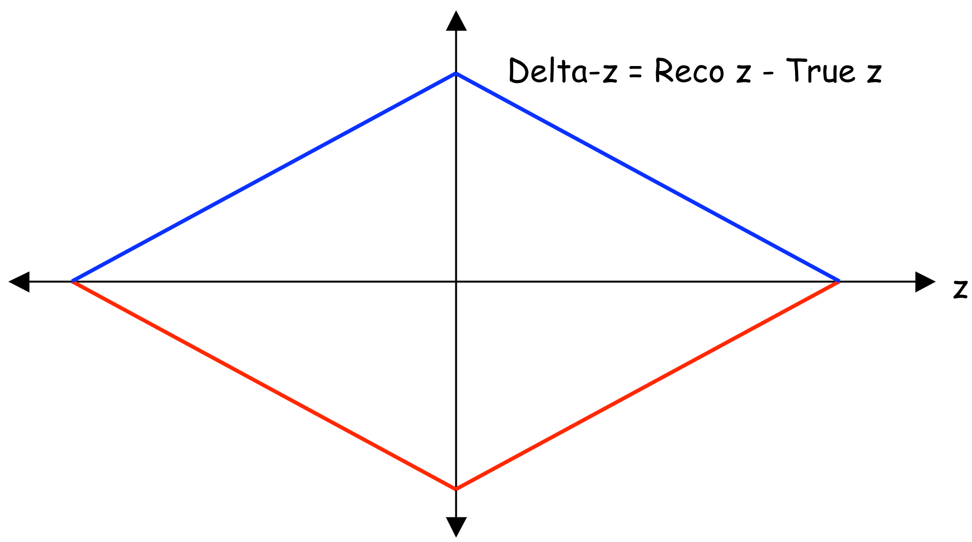


Lasers with known zs

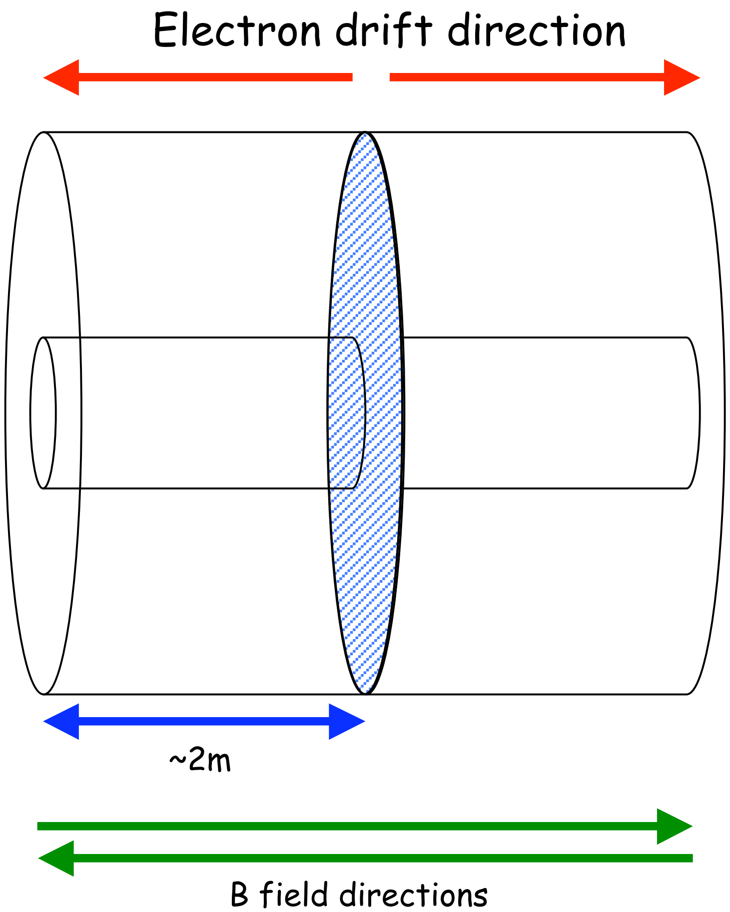
Which color is the case where the DV is too low?

- DV too low (relative to expectations) -> clusters arrive later than we expect
- Later means that reco z is less than true z

Everything affects this quantity
- Pressure (main variation)
- Temperature
- E Field Variations



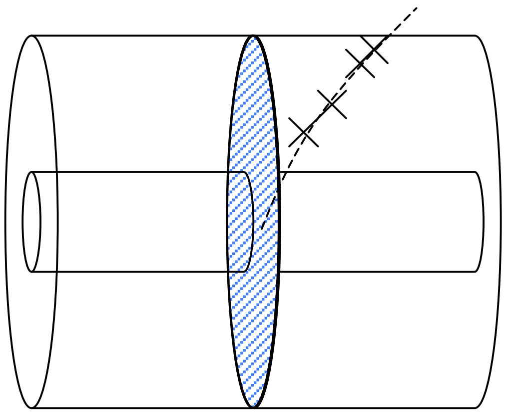
Spacecharge



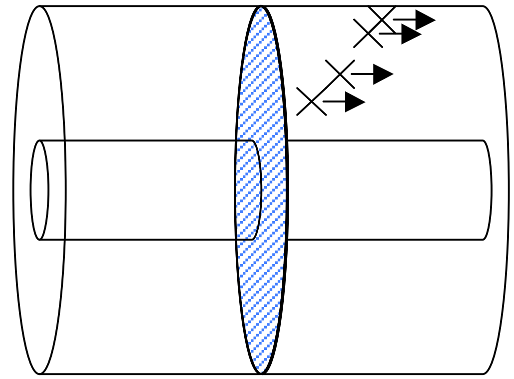
At any given instant can have 300 bunch crossings worth of electronic charge in the TPC
-> Pileup

At any given instant you have 300*(5.5/7.5e-5)~73000 bunch crossings worth of ionic charge in the TPC!!!
-> This is spacecharge

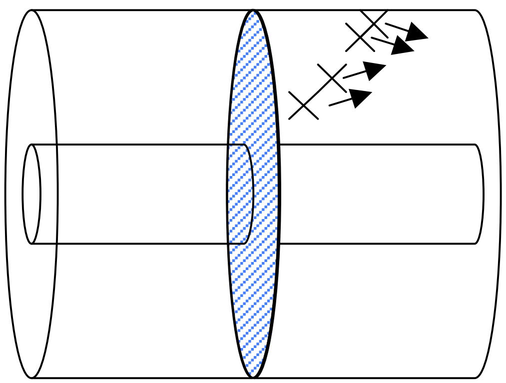
What does Spacecharge do?



Track traverses TPC liberating clusters of charge



The clusters drift towards the anodes because of drift field



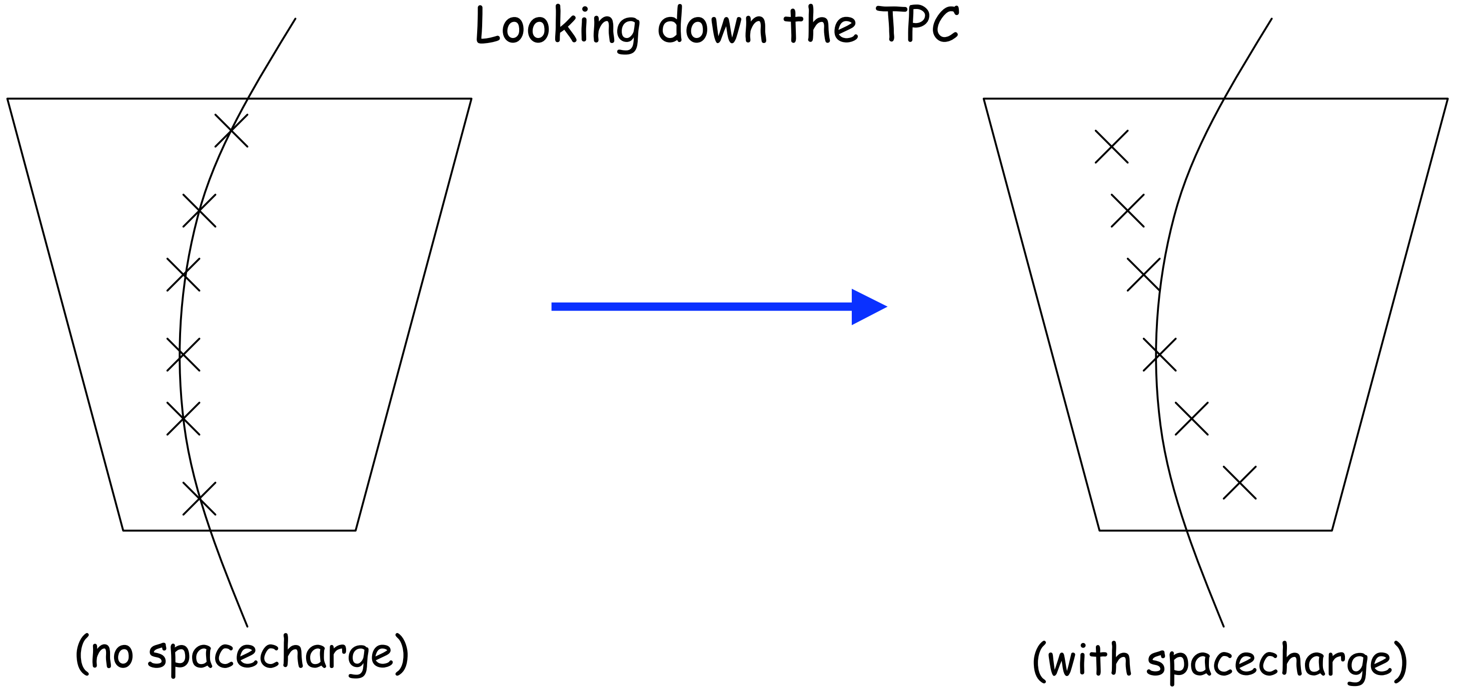
With spacecharge, the clusters feel another pull towards the middle radius of the TPC (just another E field) - The farther they travel in z, the farther they moved in (r,phi).

What does Spacecharge do?

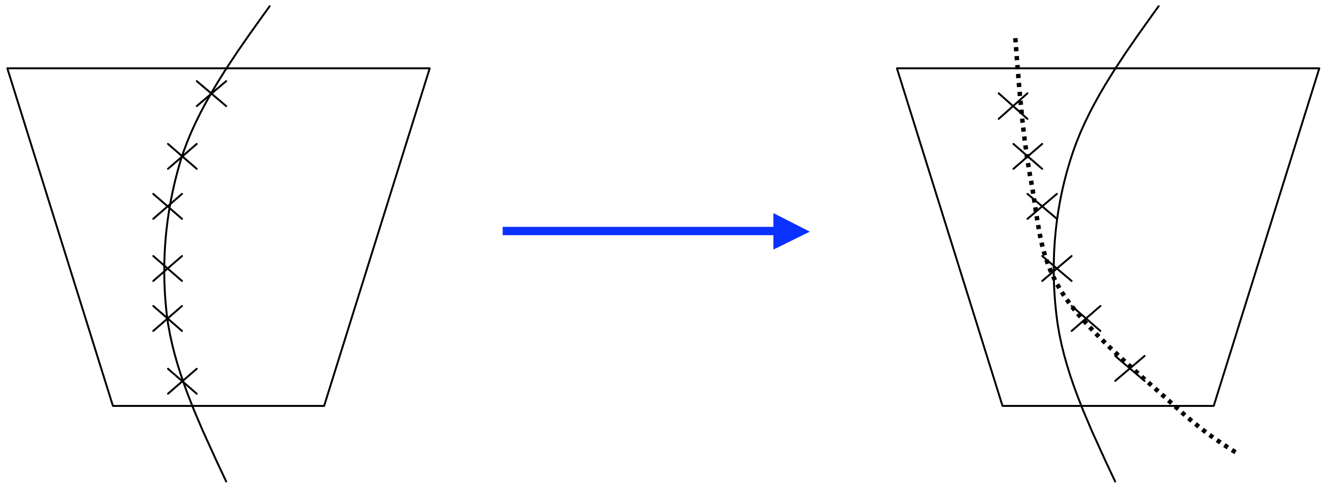
Because the charges acquire a velocity perpendicular to the B field (a radial velocity) we get a vxB force as well!

This tends to twist the clusters around the middle (in radius) of the TPC. This will change the curvature of the tracks

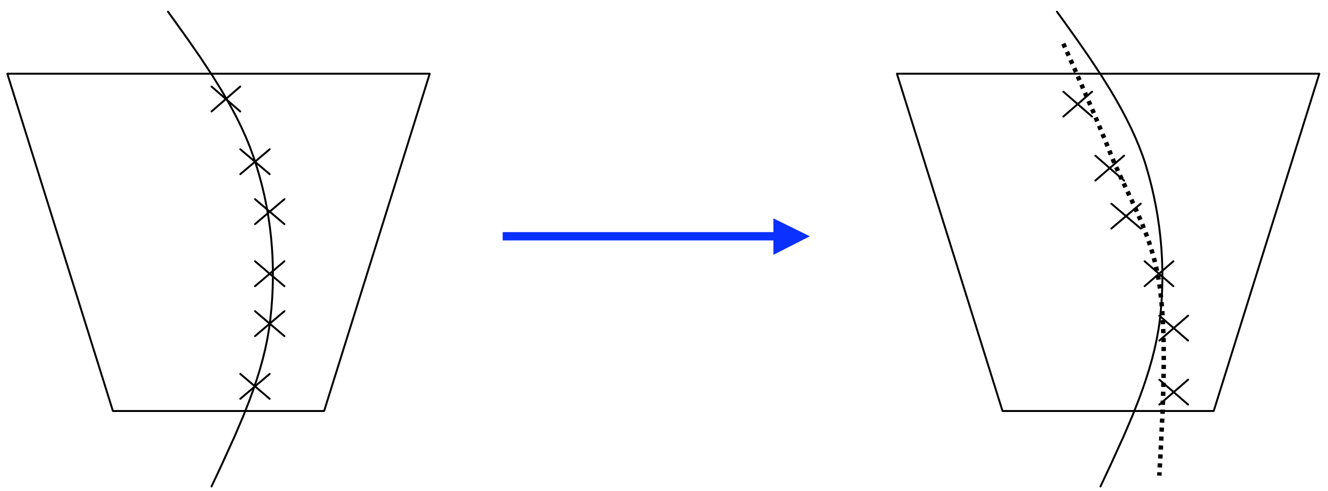
Looking down the TPC



Spacecharge and Track Charge

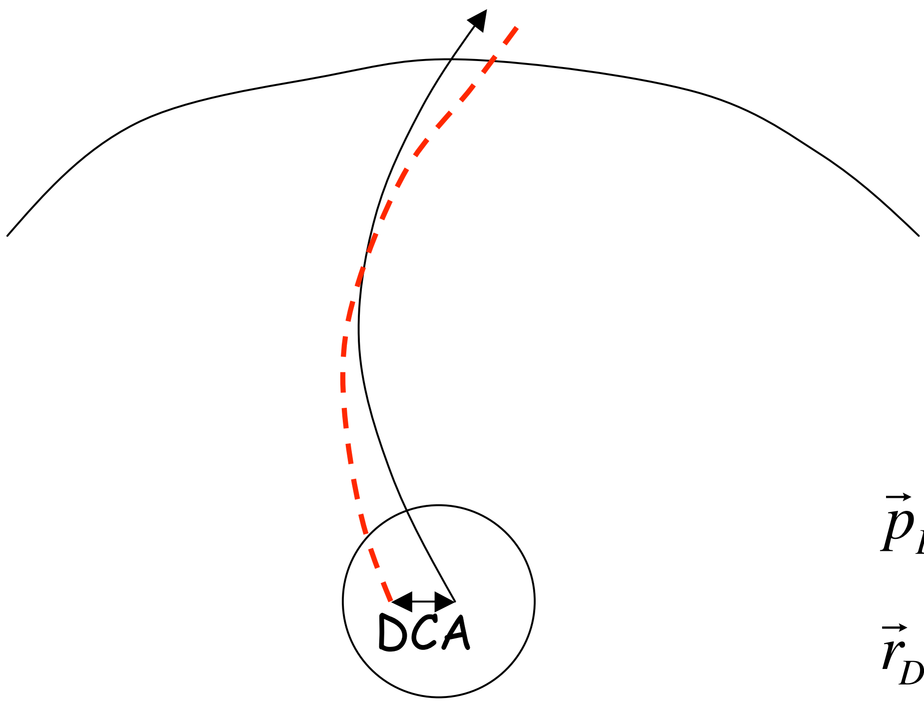


(no spacecharge) (with spacecharge)



(no spacecharge) (with spacecharge)

Measure of SC



"signed" DCA

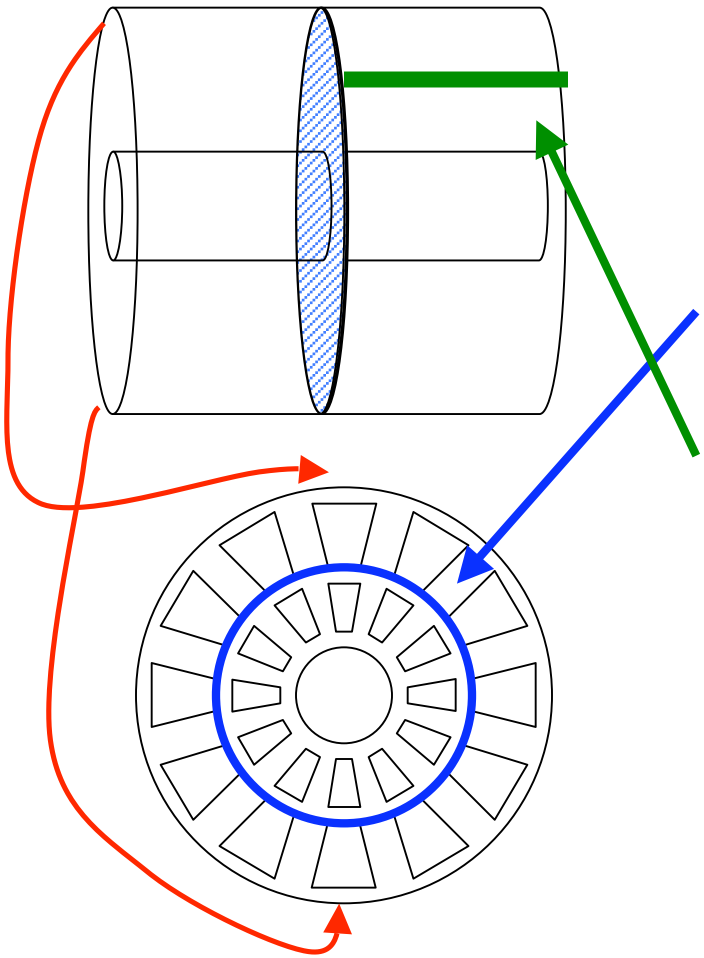
$$sDCA = \frac{\left(\vec{p}_{DCA} \times \vec{r}_{DCA}\right)_z}{\left|\left(\vec{p}_{DCA} \times \vec{r}_{DCA}\right)_z\right|} \left|\vec{r}_{DCA}\right|$$

$\vec{p}_{DCA}$ - momentum vector at the DCA to vertex

$\vec{r}_{DCA}$ - vector from vertex to the DCA

The average of the sDCA should be at 0 in a perfect world. In order to see that there is no mis-calibration we typically look at this quantity as a function of the vertex-z.

Gridleak

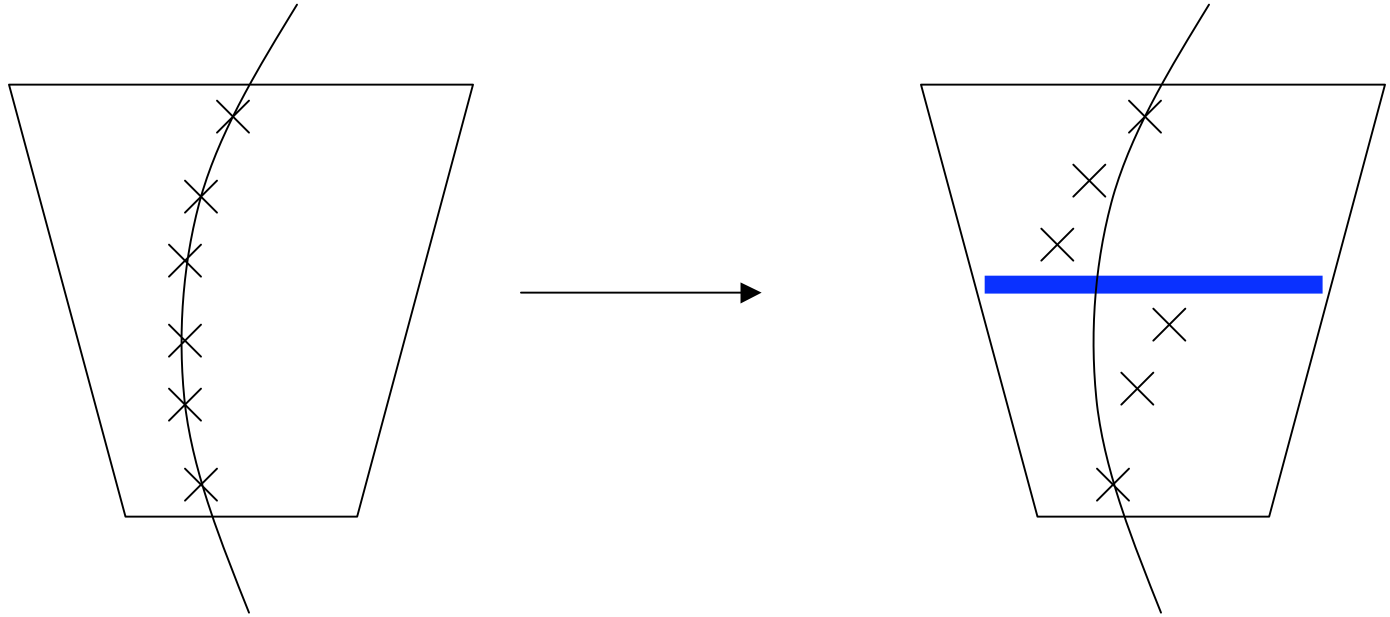


In addition to the diffuse volume filling spacecharge we've found a dense ribbon of charge flowing out of the gap between the gating grid between the inner and outer sectors

This ribbon of charge will then travel from the gating grid towards the central membrane.

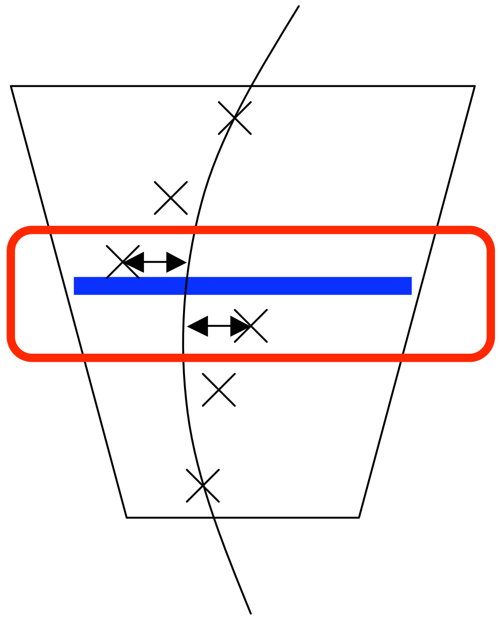
The density of the charge in the gridleak is usually ~10x higher than in the spacecharge and because the two should be related, so we define the amount of gridleak as a multiplicative factor of the spacecharge.

What does Gridleak do?



The ribbon of charge causes a shearing force -> clusters on one side are pushed one way whereas on the other side they are pushed the other way.

Measure of GL



We define a variable called gaps which is the sum of the signed distance of the two closest pad hits to their track (different signs for different halves of the TPC and in different years the two closest padrows are different.. padrow 13 problem with old electronics)

In a perfect world you would hope that there would be no offsets and thus gaps would be zero.

gaps = f(east|west,padrow 12|13)*dist(cluster on 12|13,track)
+ f(east|west,padrow 14)*dist(cluster on 14,track)

f is just a simple sign function to make sure the east and west behave the same way in our quantity

Pileup - The new kid on the block

A topic in and of itself

No time to get into this, but it changes the expectation for what all these measures should look like and it is becoming an increasing problem

Conclusions

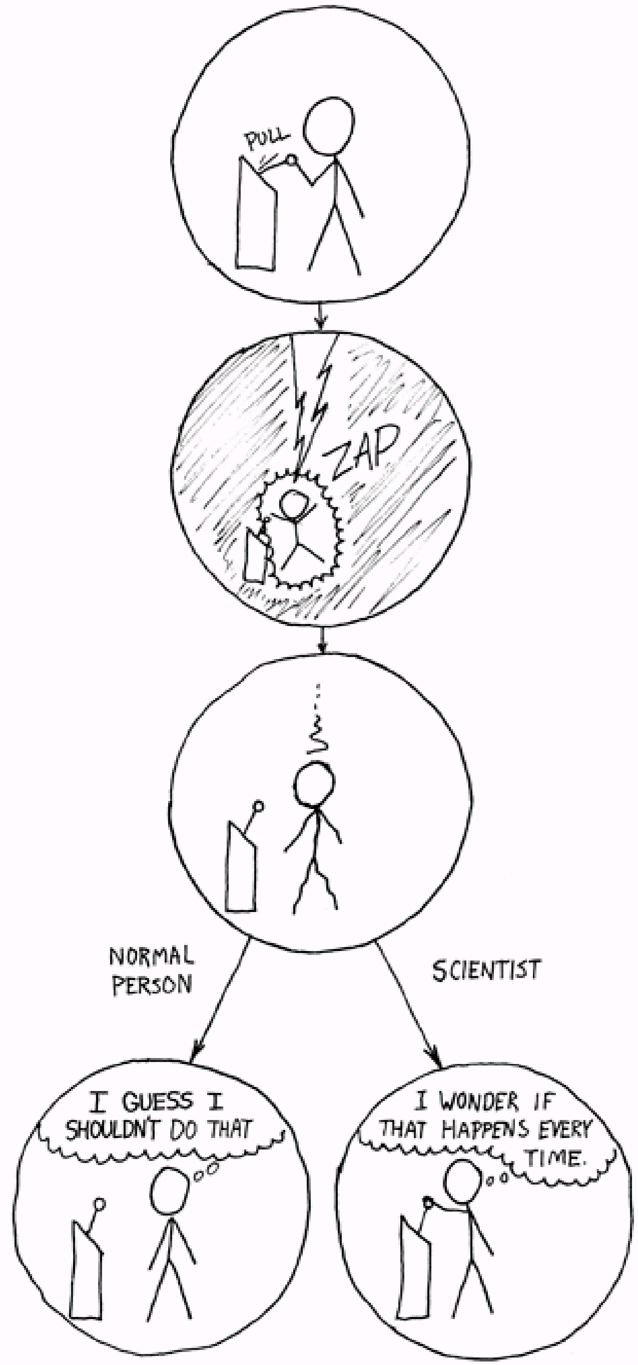
The TPC is
beautifully dynamic
and so important.

Its calibrations
are a great exercise in
creativity.

Get interested!
We need more people thinking
about the data.

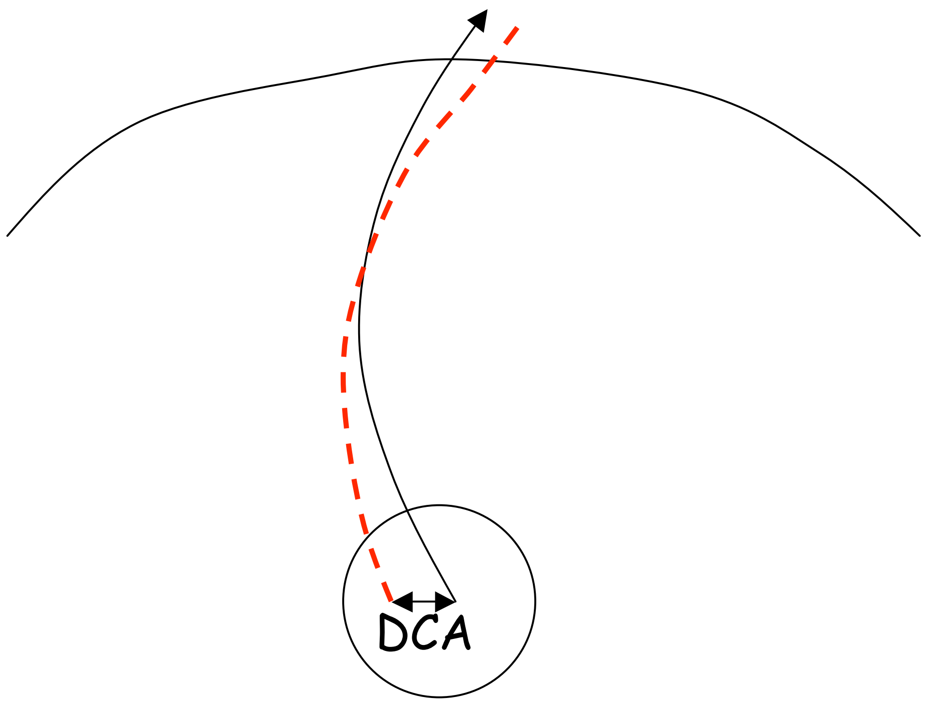
(and yes, the above statements are all Haikus)

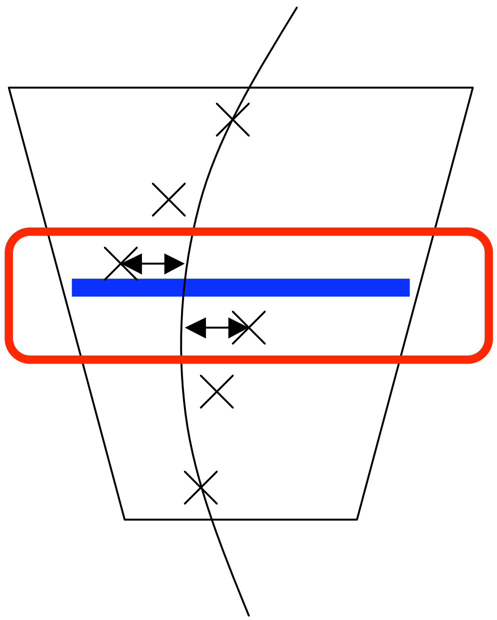
J. Seele



Backups

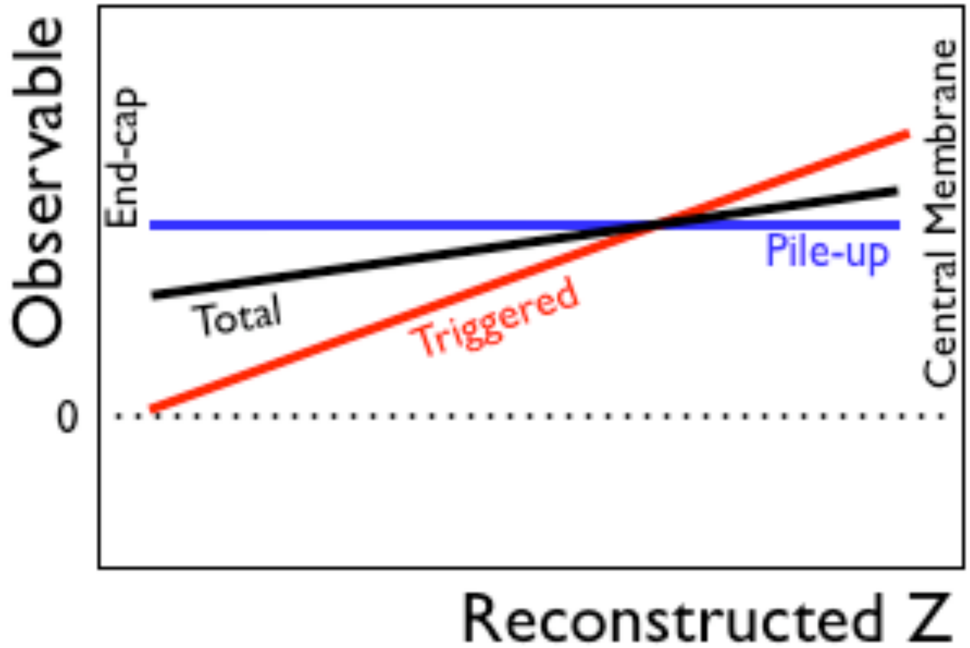
A golden braid...





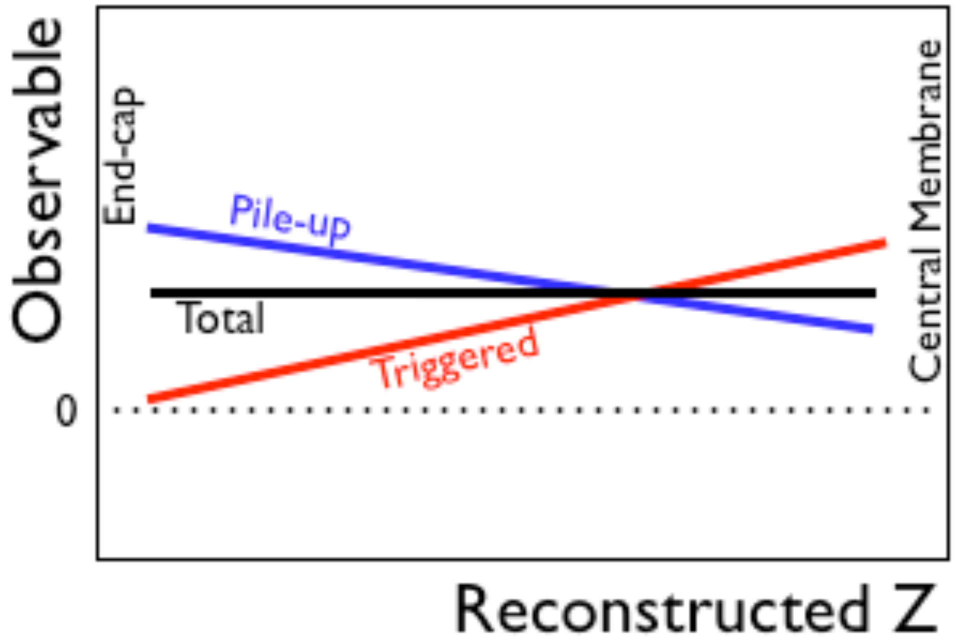
Neither of these two measures is immune to influence from the other distortion (i.e. a mis-calibrated GL will affect the sDCA and a mis-calibration SC will affect the gaps)

Measures of SC&GL in pileup



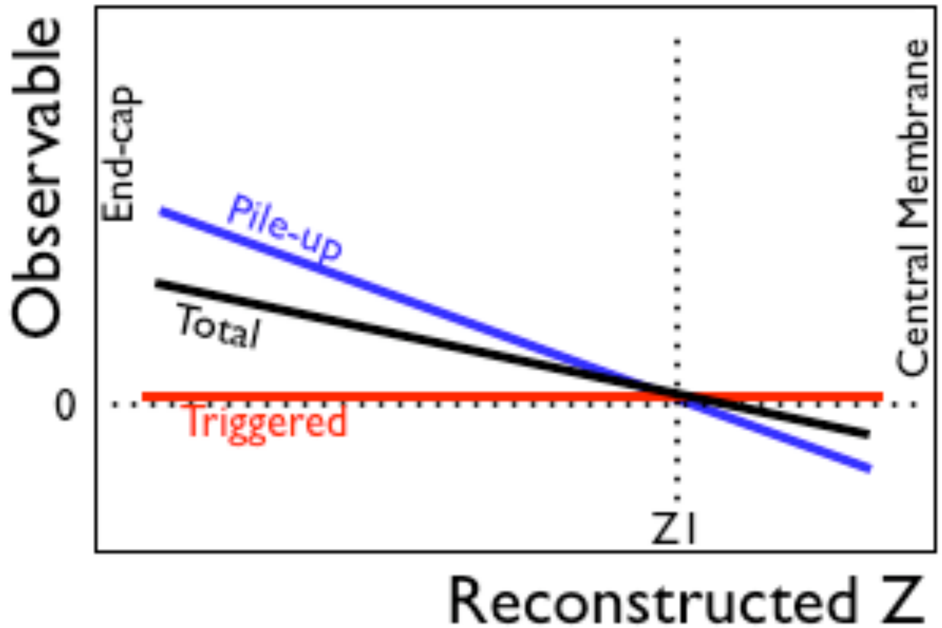
Say we didn't apply any correction for the spacecharge and gridleak and looked at the value of these spacecharge and gridleak observables. With no pileup (and perfect reconstruction) we would expect them grow linearly

Measures of SC&GL in pileup - II



What do the older calibrations try to do? They try to make the total distribution as flat as possible with the possibility that there may be an offset in the data.

Measures of SC&GL in pileup - III



But the correct thing to do is cause the total distribution to cross zero at a very specific point. This point depends on the type of measure being looked at and it depends on the vertex distribution of the events being looked at.

Some briefs words on pileup

(or why we don't live in a "perfect world")

By pileup we mean all other tracks and vertices that were not from an event that occurred during the bunch crossing that triggered the event

We can reduce it by a large amount in p+p (to a lesser extent d+Au) by only keeping vertices where a track was matched to a BEMC tower that was above threshold

But there will always will be an irreducible amount of pileup especially in Au+Au collisions where the probability for a pileup event to have a track matched to a tower above threshold is much higher due to the higher track multiplicity per event (can play games with requiring a higher number of tracks to be matched to towers, but typically in a Au+Au event you have 1500 towers lit up)

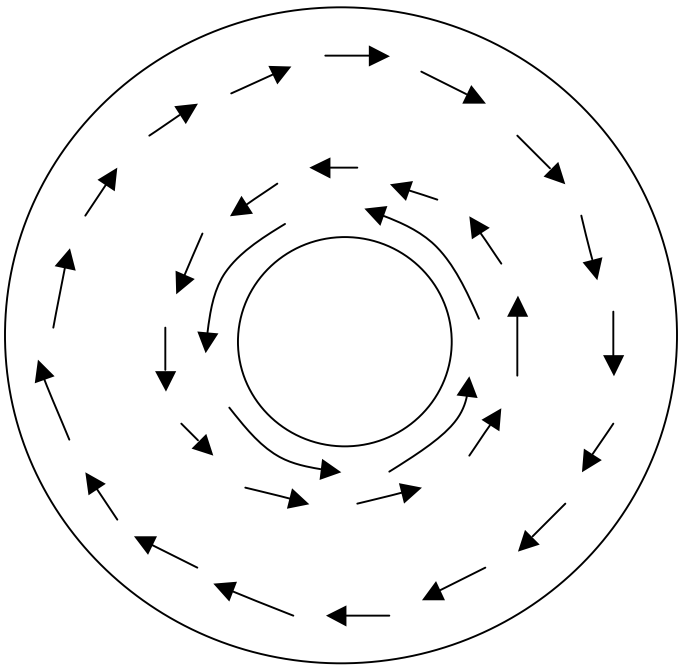
The distribution of these pileup vertices should be flat in z - Not immediately intuitive, but think about

$$d(z) = vert(z) \otimes r(\Delta z)$$

vertex distribution

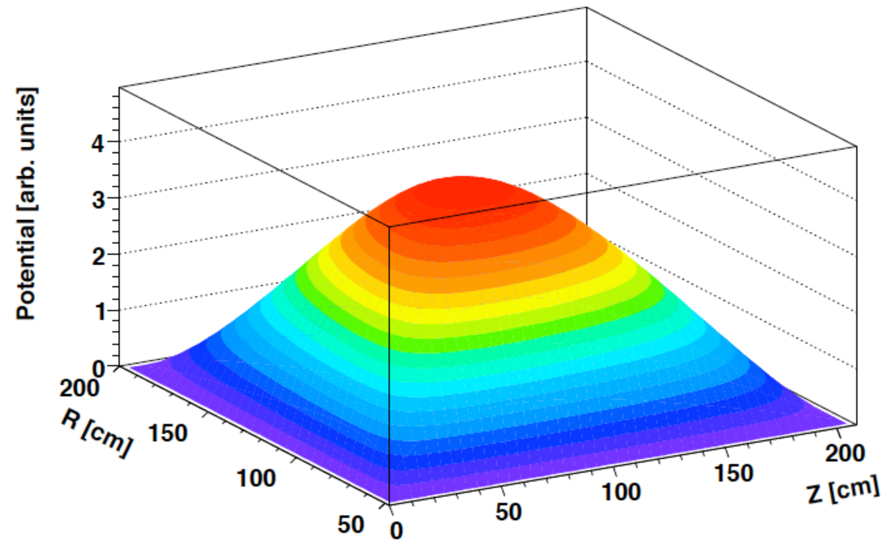
flat random offset in vertex mean

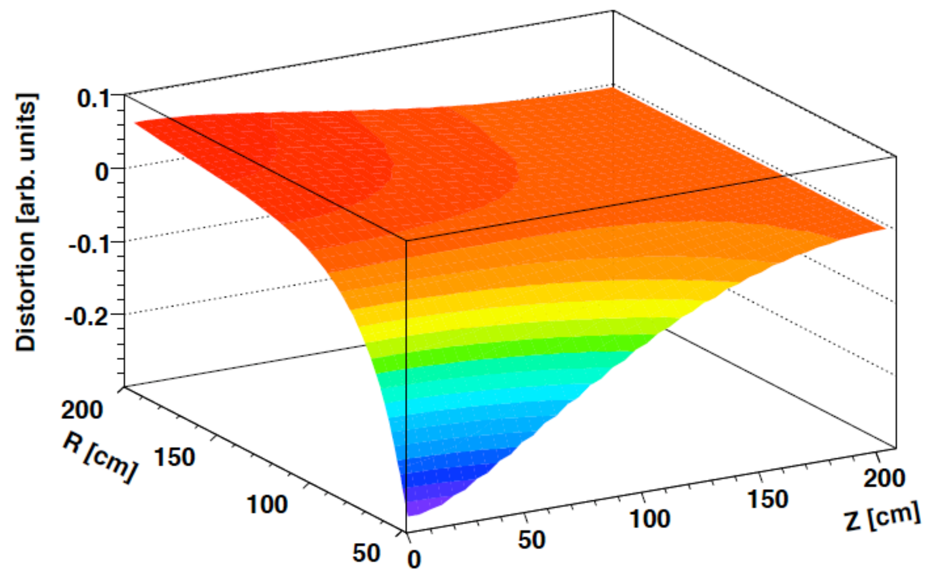
How does spacecharge affect us?



Azimuthal direction that the electron clusters are "pushed"

B-field out of plane





Two Definitions

Pileup - The "electronic" charge from tracks not associated with triggered event.

How much is in the TPC though?

How long does it take for an electron to cross the TPC?

2m/(5.5 cm/us) = 36.3us

Electronic charge from events +- 36.3us of the triggered event are among the tracks of the triggered event

Spacecharge - The "ionic" charge from tracks that builds up in TPC

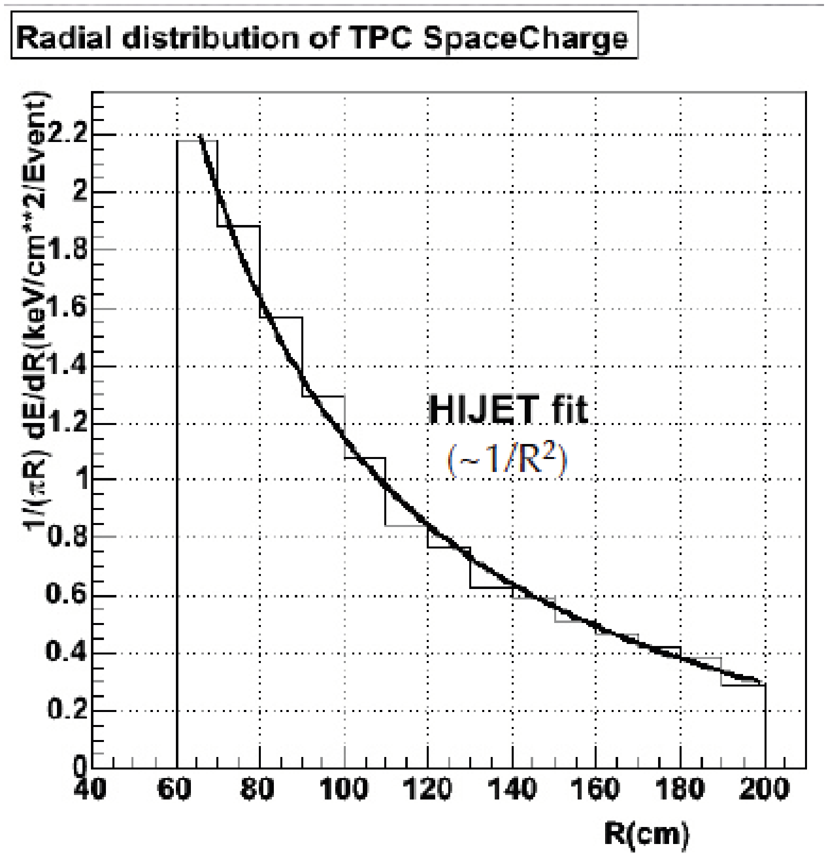
Argon ions are much slower… drift velocity ~scales with mass

$2m/(5.5cm/us * m_e/m_{Ar}) = 2.65s$ (maybe be more like ~1s)

Ionic charge from events +- 1s of the triggered events is in the TPC

x27,000 more ionic than electronic charge!

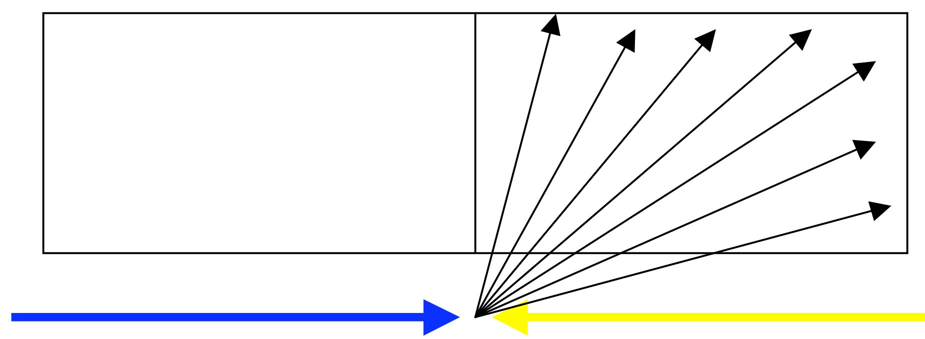
Geometry of spacecharge - I



Empirically, the integrated charge at a radius r goes as ~1/r^a where a is a bit less than 2

A combination of a few effects

- Tracks are !flat in eta (at mid-rapidity)
- Contributed charge for a given radius increases with track rapidity -> 1/sin(theta)
- Integrating charge as a function of r adds a slight logarithmic dependence



Geometry of spacecharge - II